

AMBIENT AIR QUALITY
IN THE
SARNIA AREA

ANNUAL REPORT - 1988

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AMBIENT AIR QUALITY IN THE SARNIA AREA
ANNUAL REPORT - 1988

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Southwest Region
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SUMMARY

Ambient air quality monitoring in the Sarnia area during 1988 revealed that levels of most air pollutants are normally low. However, there were occasions when air quality was poor or moderate. The most remarkable feature about 1988 air quality was the great increase in high ozone levels compared to other years in this decade. Elevated levels of ozone occur primarily as a result of long-range transport of ozone and precursor chemicals that react photochemically to produce ozone. In the spring and summer of 1988, ozone levels were higher than normal throughout southern Ontario and much of the United States. The increase has been attributed to unusual meteorological conditions and not to an increase in pollutant emissions. Ontario is taking action to reduce ozone levels by developing new legislation controlling point sources and placing more stringent controls on motor vehicles. However, satisfactory levels of ozone will not be achieved without major cutbacks of emissions in the United States.

Levels of total suspended particulates were unsatisfactory in the immediate vicinity of Holmes Foundry until September 1988 when the plant shut-down. The sulphur dioxide 24-hour criterion for desirable ambient air quality was exceeded on 1 day in downtown Sarnia during a period of unusual meteorology. This was the only excursion above the criterion since 1981 when new control legislation was enacted.

Fluoride levels south of Courtright have been lower for the past two years which corresponds to cutbacks in emissions from Canadian Industries Limited.

In June 1988 the Province's Air Quality Index was incorporated into the Sarnia air quality monitoring network. The AQI reached the poor category on two occasions because of ozone levels.

INTRODUCTION

The ambient air monitoring network of the Ministry of the Environment measures the levels of a number of pollutants that may directly or indirectly adversely affect health, vegetation or the enjoyment of property. Data on levels of pollutants are compared with Ontario's criteria for desirable ambient air quality. Thus, excursions above these criteria reflect undesirable conditions. Data are also used to determine trends in air quality and therefore, the effectiveness of pollution abatement, as well as to provide information on the effect of specific sources of pollutants and to formulate strategies to control pollution.

An Air Quality Index was incorporated into the Sarnia air quality monitoring network in June 1988. The AQI provides hourly reports on air quality based on six pollutants and includes the Air Pollution Index which is based on two pollutants.

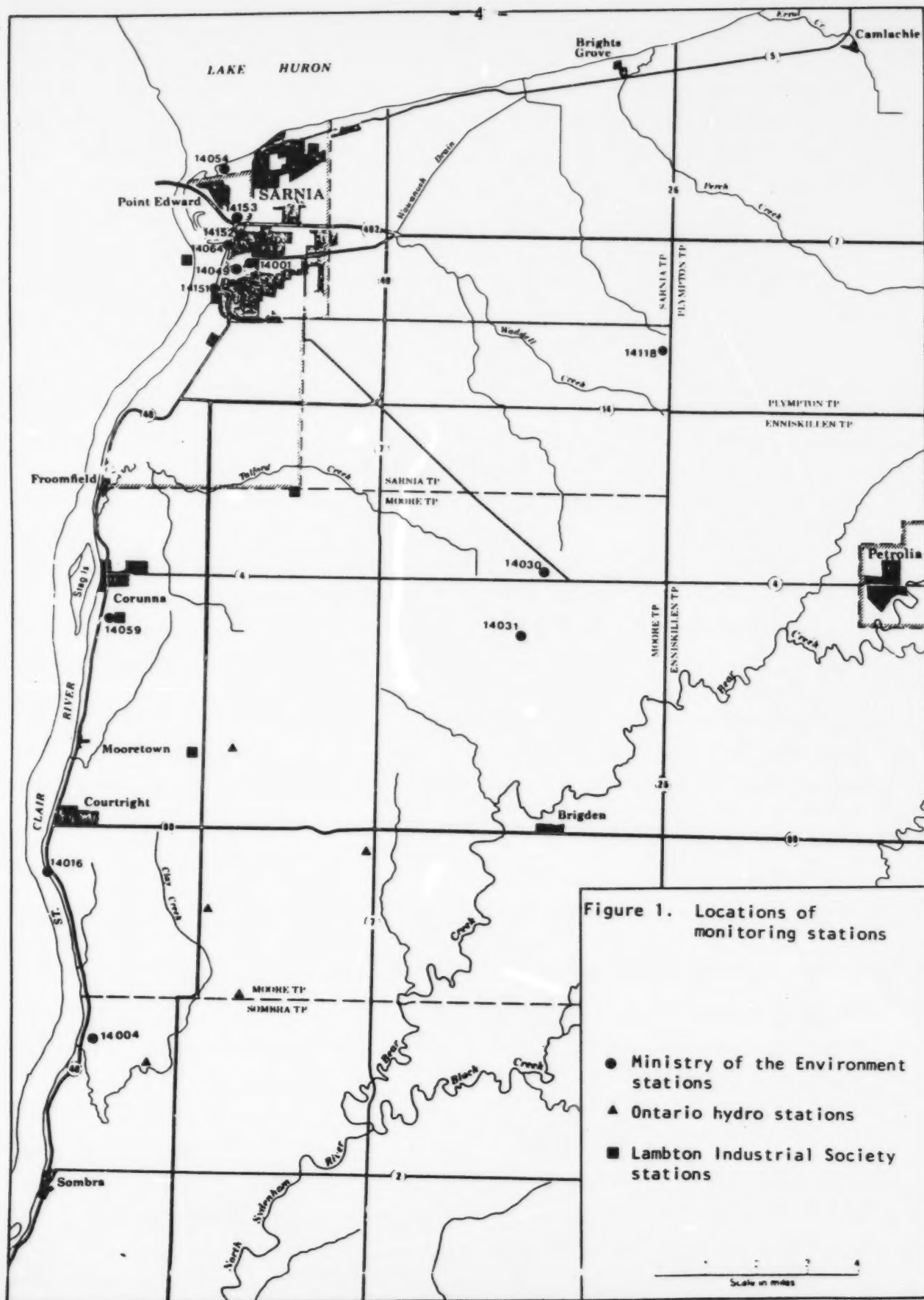
Ontario Hydro, the Lambton Industrial Society and private industry also operate ambient air monitors in the Sarnia area. In 1989 the Ministry began a co-operative monitoring program for volatile organic compounds with Environment Canada. The Ministry also conducts special air monitoring surveys for short periods of time as well as conducting phytotoxicology surveys to determine the effects of air pollutants on vegetation. The results of the special surveys and monitoring by other groups are not contained in this report.

Emissions from industrial and other stationary sources of pollutants in Ontario are regulated by this Ministry through a Certificate of Approval. In the Sarnia area, there is a special control strategy for sulphur dioxide. This special control strategy requires major sources of sulphur dioxide to provide supplementary control if the ambient levels of sulphur dioxide approach the 24-hour criterion for desirable ambient air quality.

DESCRIPTION OF MONITORING NETWORK

Continuous and intermittent monitors for determining levels of pollutants in ambient air are maintained by the Ministry at sites dispersed throughout the Sarnia area. However, monitoring is more intensive in the area of downtown Sarnia because it has a higher potential for elevated levels of pollutants than most other areas in Lambton County. This higher potential is a result of the downtown area being affected by emissions from industries and power generating plants to the south, as well as dense vehicular traffic and commercial establishments in the downtown core. The industries and power generating plants to the south of Sarnia tend to be located along the St. Clair River and plumes from different sources of emissions can create an additive impact when they impinge on the downtown area. Furthermore, the taller buildings situated in the downtown core affect wind currents and may bring pollutants from aloft down towards ground level.

The location of the Ministry's fixed monitoring sites are illustrated in Figure 1. Also included in Figure 1 are the locations of monitoring sites of Ontario Hydro and the Lambton Industrial Society. Specific Ministry locations and the pollutants monitored are listed in Table A1, Appendix 1.



Criteria for desirable ambient air quality and the supporting rationale for the establishment of these criteria appear in Table A2, Appendix 1.

METEOROLOGICAL DATA

Meteorological data are utilized in predicting the stability of the atmosphere which affects the dispersion of pollutants. These data also assist in identifying sources of pollutants and in validating mathematical models designed to predict the dispersion of air pollutants.

The main meteorological tower in the area is located at station 14016 immediately south of Courtright. Wind speed and direction are measured at 10 metres, 30 metres and 92 metres above ground level. In addition, ambient temperature is measured at the 10-metre level and the gradients in temperature between the 10-metre level and the 30- and 90-metre levels are determined. These meteorological data are transmitted to Toronto by a telemetry system. Meteorologists utilize the data to forecast the stability of the atmosphere. This forecasting feature is an intrinsic part of the Air Quality Index and the Lambton Industrial Meteorological Alert, both discussed later in this report.

Meteorological data from station 14016 have been used in computing the average concentrations of some pollutants for specific wind directions and in determining the number of hours that the criteria for ozone have been exceeded for different wind directions.

A summary of the frequency of winds for different directions at the 30-metre level of station 14016 appears in Table A3, Appendix 2. The data indicate that the prevailing winds are from the south.

MONITORING PROGRAM AND RESULTS

PARTICULATES

Primary sources of man-caused emissions of particulates to the atmosphere are vehicular traffic, materials handling and combustion processes. Wind-blown particulates from open fields, sand and coal piles, roadways and roofs are also significant sources.

Measurements for particulates are reported as total suspended particulates and soiling index. Total suspended particulates are determined by drawing measured volumes of air through a pre-weighed filter for 24-hours and subsequently weighing the quantity of particulates collected on the filter. Soiling index is measured by determining the difference in the amount of light that is transmitted through a filter before and after ambient air is drawn through the filter for 1 hour. The amount of light transmitted through the filter is affected by quantity, size, shape and opaqueness of particulates retained on the filter. Soiling index can be correlated to levels of suspended particulates and can be determined without the time-consuming laboratory analysis required for determining concentrations of total suspended particulates. For these reasons, soiling index is used as a substitute for suspended particulate values when data are required quickly such as in the Air Pollution Index.

Total Suspended Particulates

Two criteria for desirable ambient air quality exist for total suspended particulate matter. One is 120 micrograms of suspended particulates per cubic meter of air ($\mu\text{g}/\text{m}^3$) averaged over a 24-hour period. The other is an annual

geometric mean of 60 ug/m³. The criterion for 24 hours is based on impairment of visibility and adverse health effects associated with combined concentrations of sulphur dioxide and suspended particulates. The annual criterion is based on public awareness of suspended particulates and property damage.

During 1988 total suspended particulates were sampled at 10 sites in the Sarnia area. At 7 of the sites a 24-hour sample was collected on an every-sixth-day schedule for the year. At two new sites near Holmes Foundry sampling was conducted on an every-three-day schedule while at another site, station 14016 near Courtright, sampling was conducted on a daily basis. The national monitoring networks of the United States and Canada operate on the same every-sixth-day sampling schedule for suspended particulate matter. The Ministry operates the daily schedule at station 14016 to evaluate how representative the every-sixth-day schedule is of the complete year. The 1988 data indicate that the every-sixth-day schedule was reasonably representative of conditions throughout 1988. Table 1 contains a summary of the 1988 total suspended particulate data. Figure 2 shows the annual geometric means and the frequencies of excursions above the 24-hour criterion for 1988 at the approximate locations of the monitoring data.

There were several interesting features about the 1988 levels of suspended particulates. At station 14151, located in the southern section of downtown Sarnia, the 24-hour criterion was exceeded more frequently in 1988 than in 1987. This increase in frequency of excursions did not occur at other stations in the downtown area, such as stations 14001 and 14064. The increase at station 14151 is attributed to an

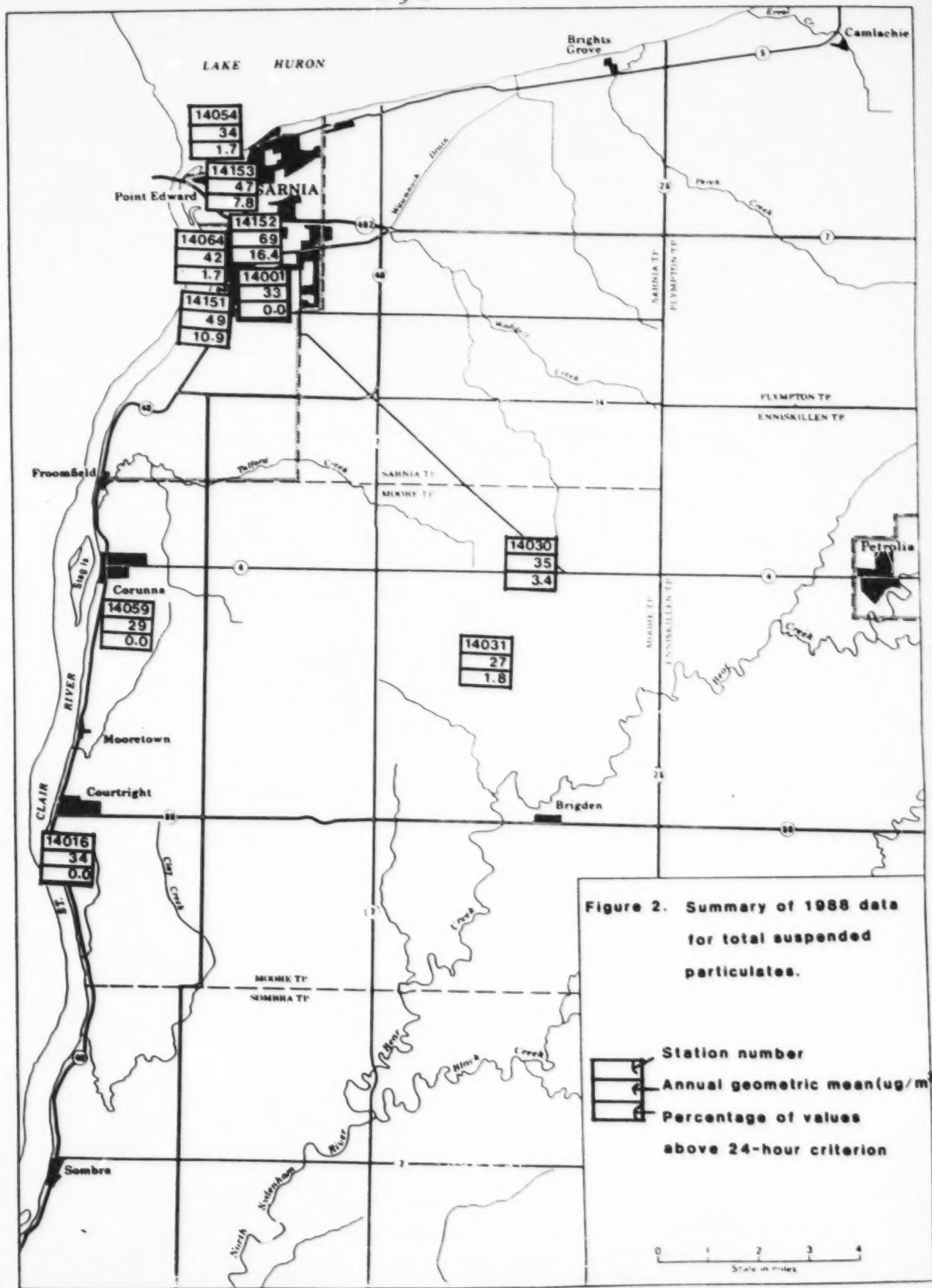
Table 1. Summary of 1988 data for total suspended particulates

Station No.	No. of samples collected	Annual geometric mean ($\mu\text{g}/\text{m}^3$)	No. of values greater than 24-hour criterion	Percentage of Values greater than 24 hour criterion
14001	56	33	0	0
14016	350	34	0	0
14016-S	60	33	0	0
14030	56	35	2	3.4
14031	55	27	1	1.8
14054	59	34	1	1.7
14059	58	29	0	0
14064	58	42	1	1.7
14151	55	49	6	10.9
14152	116	69	19	16.4
14153	115	47	9	7.8

Note: Data for station 14016-S are every-sixth-day sampling results extracted from the daily sampling data for station 14016.

The annual criterion for desirable ambient air quality is $60 \mu\text{g}/\text{m}^3$.

The 24-hour criterion for desirable ambient air quality is $120 \mu\text{g}/\text{m}^3$.



unknown local source. All but one of the excursions above the 24-hour criterion occurred during the period of May to July, 1988. If frequent excursions of the criterion occur in the future, a more extensive investigation for the cause will be mounted. The annual criterion was exceeded only at monitoring station 14152, located near Holmes Foundry.

Stations 14152 and 14153 began operation in 1987 to assess impact of emissions from Holes Foundry on ambient air quality. The higher levels of total suspended particulates at stations 14152 and 14153 have been linked to emissions from Holmes Foundry through an evaluation of meteorological data and increases in iron, manganese and free carbon concentrations in suspended particulates. Iron and manganese are reported in the literature as good elements to trace foundry emissions and free carbon is also emitted by foundry operations.

The impact of the emissions from Holmes Foundry have been shown to be very localized as the increase in particulates, iron and manganese noted at stations 14152 and 14153 are not usually noticeable at station 14064 in Centennial Park. On September 16, 1988, Holmes Foundry stopped production and permanent decommissioning of the site began.

An approximate indication of the impact of the emissions from Holmes Foundry can be obtained from reviewing the average 1988 levels of total suspended particulate, iron and manganese determined for stations 14064, 14152 and 14153 before and after the shutdown of production at the foundry. These values which appear in Table 2 show appreciably higher levels of these parameters occurred at station 14152, located closest to the foundry, before shutdown. At station 14153, located somewhat farther from the foundry, higher levels

of these parameters were experienced before shutdown but not as high as at station 14152. The levels of these parameters at station 14064 located farther from the foundry, before and after shutdown, were quite similar and comparable to the post shutdown values obtained at stations 14152 and 14153.

Table 2. Summary of before and after shut-down conditions near Holmes Foundry.

Station	Average 1988 levels before shutdown			Average 1988 levels after shutdown		
	TSP	Iron	Manganese	TSP	Iron	Manganese
	(ug/m ³)			(ug/m ³)		
14152	96	3.28	0.21	49	0.79	0.04
14153	60	1.16	0.11	46	0.80	0.04
14064	48	0.76	0.04	46	0.62	0.02

The levels of suspended particulates for the general Sarnia area have been appreciably lower in the 1980's compared to the 1970's. This improvement is illustrated by Figures 3 and 4. Figure 3 shows the trend in the average geometric mean for five monitoring sites ⁽¹⁾ in operation since 1972. Figure 4 illustrates the trend in the average frequencies of excursions above the 24-hour criterion for these same monitoring stations.

In general, levels of total suspended particulates in Sarnia compare very favourably with levels experienced in other areas of Ontario.

⁽¹⁾ The stations are 14001, 14016, 14054, 14064 and 14151. Station 14064 replaced station 14049 in 1978 but comparison studies revealed that the levels of suspended particulates were similar at both sites.

Figure 3. Trend in annual levels of total suspended particulates based on averaged data for five monitoring stations.

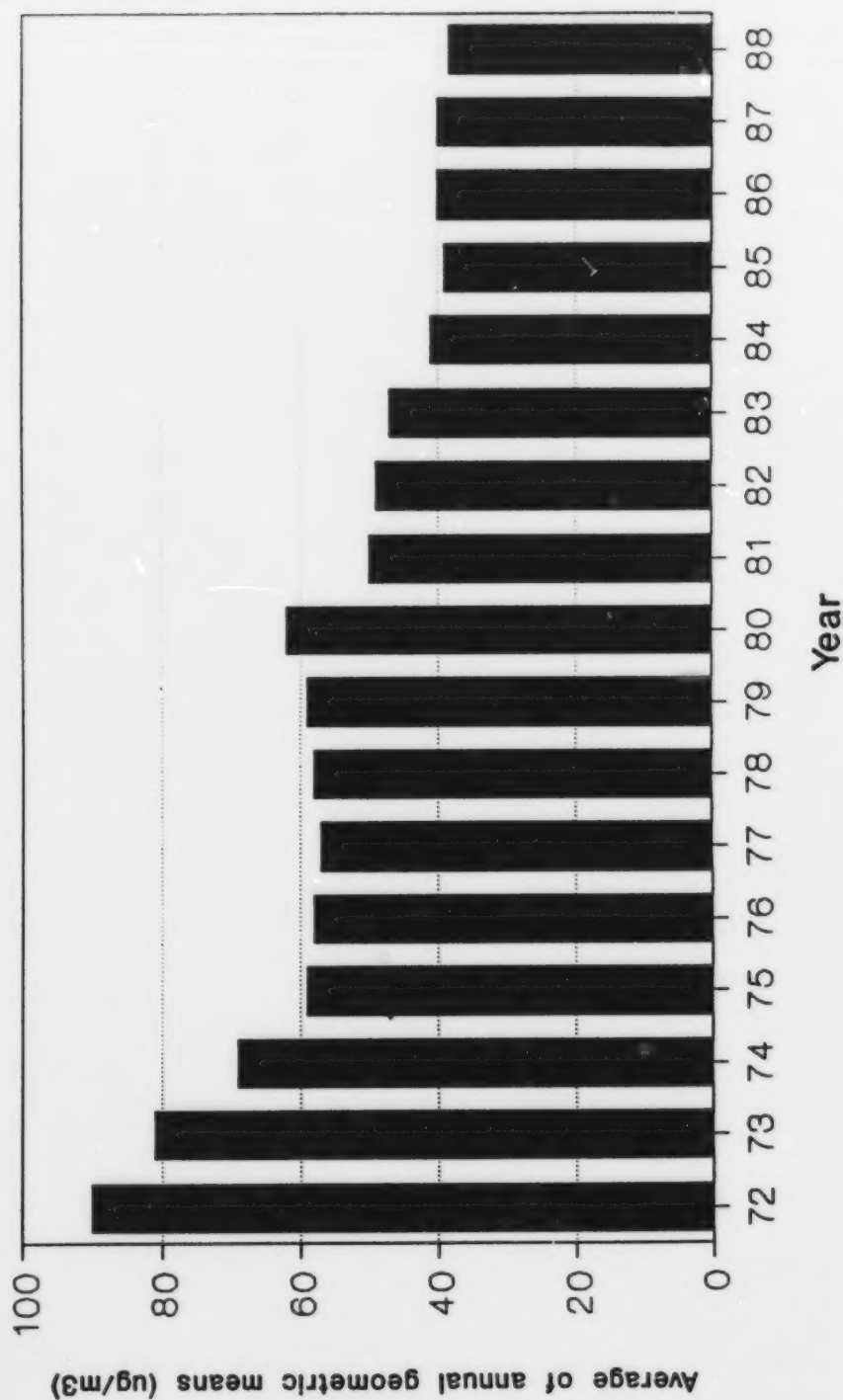
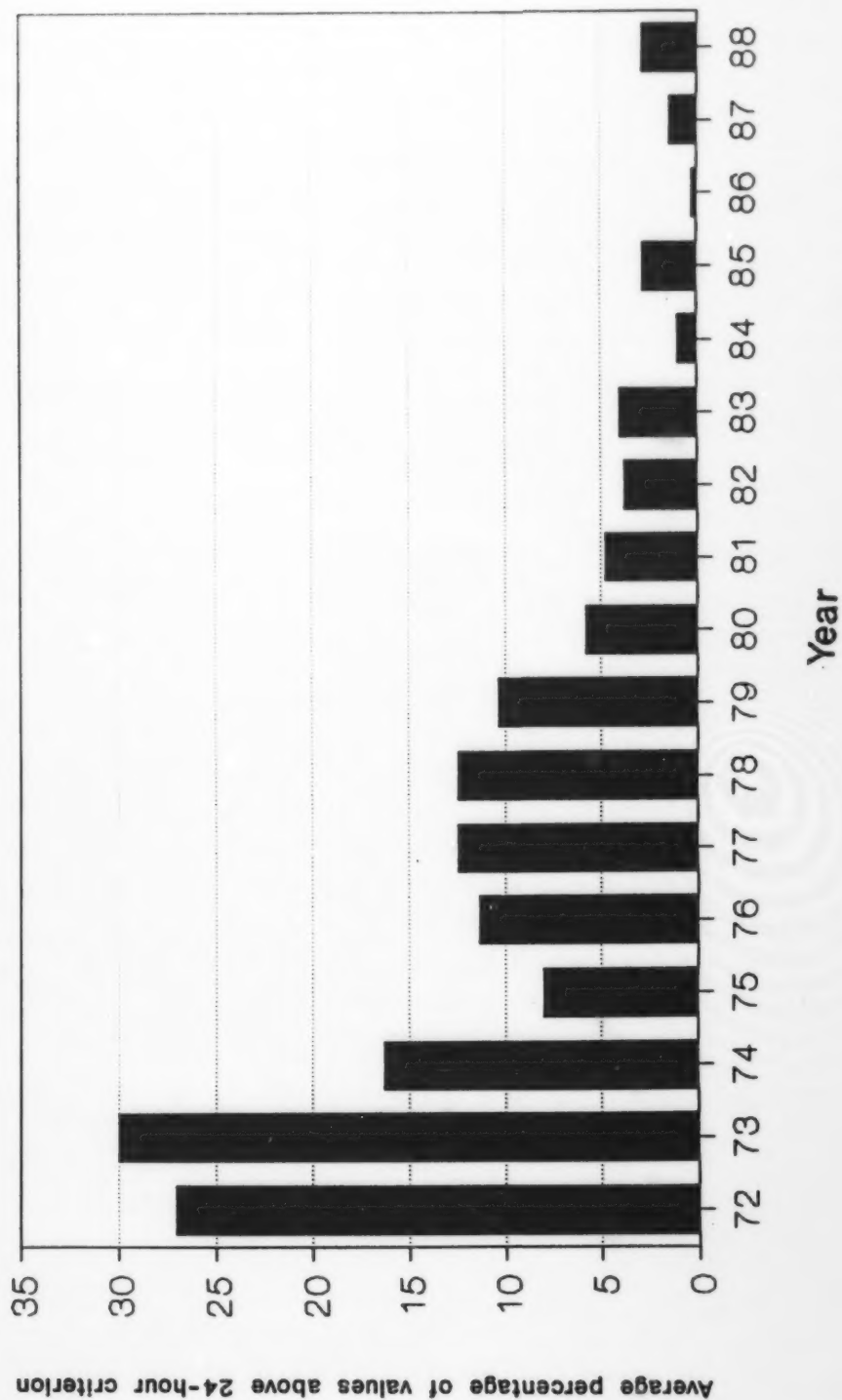


Figure 4. Trend in excursions above 24-hour criterion for total suspended particulates based on data from five monitoring stations



Chemical Analysis of Suspended Particulates

Samples of suspended particulates collected at 6 stations in the Sarnia area during 1988 were analyzed for various elements such as cadmium, chromium, copper, iron, lead, manganese, nickel and vanadium. For four of these stations samples were also analyzed for nitrates and sulphates. For two stations (14152 and 14153) samples were analyzed for total carbon, free carbon and carbonate. A summary of data from 1976 through 1988 for these constituents is contained in Table A4, Appendix 3.

A review of Table A4 reveals that iron and manganese levels were appreciably greater at stations 14152 and 14153 than at the other stations for which samples were analyzed for these elements. As mentioned previously iron and manganese are emitted from iron foundries and the results provide valuable information linking elevated total suspended particulate levels to foundry emissions.

Data for sulphates are erroneously high, based on the findings of several studies of the sampling method utilized by the Ministry. The problem may be rectified by using a different filter media and the Ministry is investigating the feasibility of changing filter media. However, other filter media usually have other liabilities that have resulted in an ideal medium not being found.

Criteria for desirable ambient air quality exist for cadmium, chromium, lead, nickel and vanadium. There have been no values above the criteria and in general, the concentrations of the various metals have been low.

SULPHUR OXIDES

Combustion of sulphur-containing fuels comprises the predominant source of man-made emissions of sulphur oxides. In the Sarnia area, large quantities of these fuels are consumed by power-generating plants in Michigan and Ontario and by petroleum and petrochemical industries located south of downtown Sarnia.

The Ministry of the Environment monitors sulphur oxides in the Sarnia area using continuous analyzers for gaseous sulphur dioxide and by analyzing suspended particulate matter for sulphate.

Throughout 1988 the Ministry measured gaseous sulphur dioxide at station 14016 south of Courtright and at station 14064 in Centennial Park, downtown Sarnia. There were 11 other sites where monitors providing continuous measurements of sulphur dioxide were operated by Ontario Hydro, the Lambton Industrial Society or private industry. Data for these sites are not included in this report but were utilized to confirm conclusions drawn from the data generated by the Ministry's instruments.

Data are reported as 1-hour average concentrations, 24-hour average concentrations (midnight to midnight) and annual average concentrations. Criteria for desirable ambient air quality are 0.25 parts of sulphur dioxide per million parts of air (ppm) averaged for a 1-hour period, 0.10 ppm averaged for 24 hours and 0.02 ppm as an annual average. The criteria for the 1-hour and annual averages are based on the protection of vegetation while the 24-hour criterion is based on the protection of human health.

In the past, there was concern about the frequency of excursions in the downtown area of Sarnia above the 24-hour criterion for desirable ambient air quality. This concern resulted in a new regulation called LIMA ⁽¹⁾ being implemented in April, 1981. This regulation requires major industrial emitters of sulphur dioxide to provide additional controls either continuously or when required by the Ministry. The Ministry may require industries to provide increased control when meteorological conditions conducive to adverse air quality are likely to persist and sulphur dioxide levels are elevated at specified monitoring sites. The specific monitoring sites consist of two in Sarnia, one in Port Huron and one in Corunna. One site in Sarnia and the sites in Port Huron and Corunna are part of the Lambton Industrial Society's monitoring network. The other site in Sarnia is the Ministry's station 14064, located in Centennial Park.

This control strategy has been very successful. Since the regulation went into effect in 1981, the 24-hour criterion was not exceeded at the Ministry's monitoring stations until January 16, 1988 when the only excursion occurred. This excursion occurred at station 14064 in Centennial Park and an excursion was simultaneously measured at the Lambton Industrial Society station on Front Street. The meteorology on January 16 consisted of strong south-southwesterly winds. Actions taken through LIMA were not effective enough to prevent the excursion as the 24-hour concentration reached 0.11 ppm. A voluntary control program was initiated by local industry to effect control measures before LIMA is called.

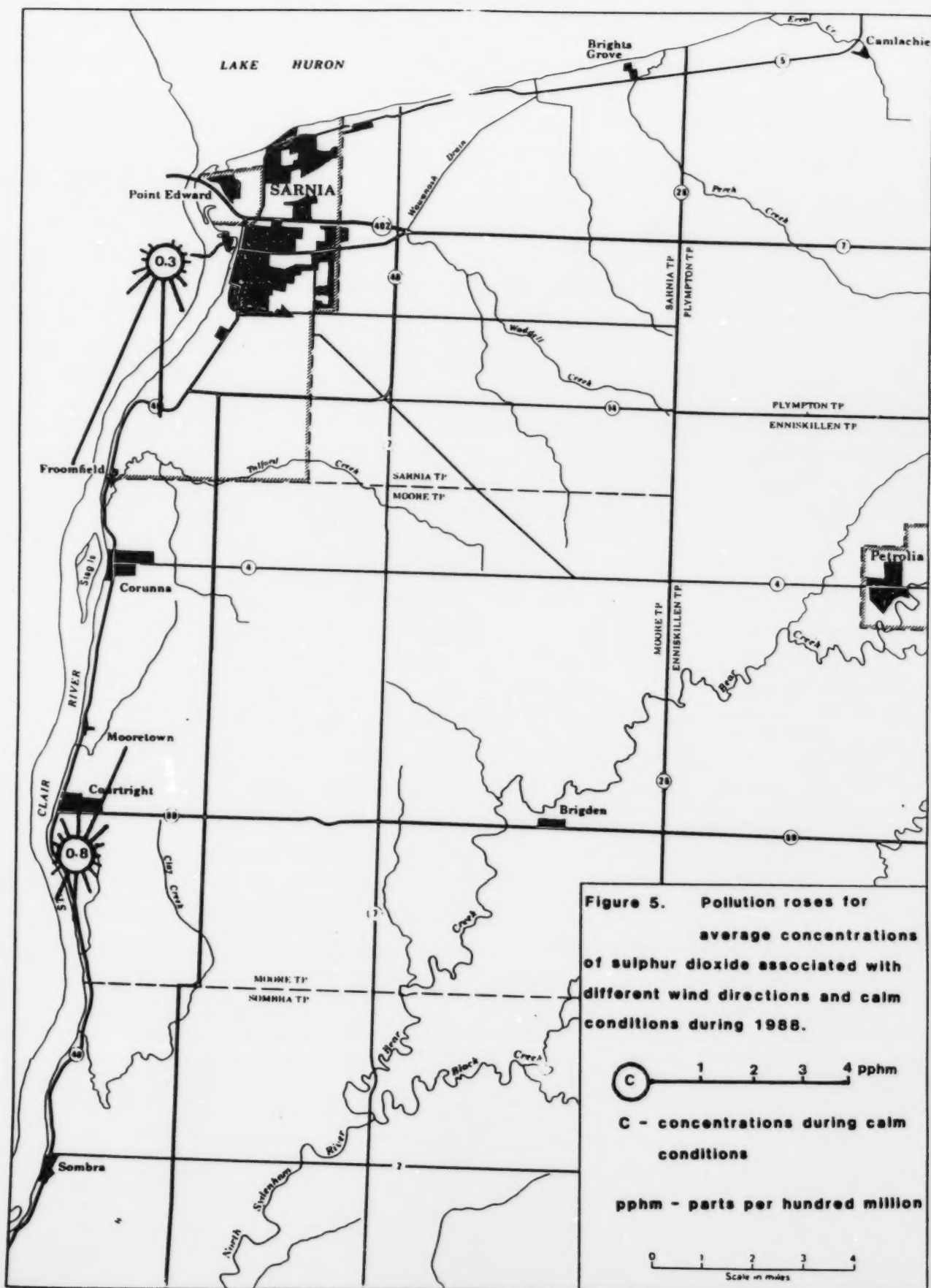
(1) Lambton Industrial Meteorological Alert

The 1-hour and annual criteria were not exceeded at the Ministry monitoring stations in 1988. A summary of 1988 data appears in Table 3.

Table 3. Summary of 1988 data for sulphur dioxide.

Station No.	Annual average (ppm)	Percentage of values above criterion		Maximum 1-hr value (ppm)	Maximum 24-hr (daily) value (ppm)
		1-hr	24-hr		
14016	0.006	0	0	0.17	0.06
14064	0.009	0	0.3	0.24	0.11

Pollution roses for sulphur dioxide measurements appear in Figure 5. The roses were created using data for wind direction and speed from the 92-metre level of station 14016 and concentrations of sulphur dioxide determined at the various stations. The length of the line corresponding to a specific wind direction indicates the average sulphur dioxide concentration when the winds are from that direction. The rose for station 14064, located in downtown Sarnia, reflects appreciably higher levels of sulphur dioxide when winds are blowing from industries located in south Sarnia and farther south. However, since the ambient air quality criteria are met, the influence of the local emission sources is not creating an apparent problem.



The rose for the station south of Courtright reveals an impact from the emission sources to the north. Any impact from the Detroit Edison St. Clair Power Generating Station located south of the monitoring stations is very minor as is the case for the Lambton Generating Station of Ontario Hydro, located to the south-southwest. However, the monitoring station is located too close to the Lambton Generating Station to measure the main impact of the generating station emissions. The monitoring network of Ontario Hydro has 5 monitoring stations located at distances where maximum impact is anticipated. Levels of sulphur dioxide at these stations were similar to levels at the Ministry station south of Courtright.

AIR QUALITY INDEX

In June 1988 the Ministry introduced the new Air Quality Index (AQI) to Sarnia. The AQI is an information system that can provide hourly reports characterizing current air quality. The AQI includes six basic air pollutants: carbon monoxide, nitrogen dioxide, ozone, sulphur dioxide, total reduced sulphur compounds and suspended particulates measured as soiling index. The Province's Air Pollution Index (API), which is an information and control mechanism based on the combined concentrations of sulphur dioxide and suspended particulates, is incorporated into the Air Quality Index. The API is computed on a running 24-hour basis while the other parameters used to calculate the AQI are either 1-hour values or in the case of carbon monoxide both an 8-hour value and a 1-hour value.

The AQI value reported is the highest value reported for any one of the parameters used in the AQI. For example, if the AQI indicates poor air quality based on ozone and good air quality based on the other parameters then the AQI is reported as poor.

The AQI is very good when the numerical value is between 0 and 15 inclusively. There are believed to be no adverse effects associated with the AQI pollutants at this level. At an AQI from 16 to 31 the air quality is good but there may be some adverse environmental effects such as slight odours and injury to some vegetation. From 32 to 49 the AQI is moderate and there may be odours and injury to vegetation. Also, due to particulates, there may be some decrease in visibility.

The AQI is poor from 50 to 99. Effects may include extreme odours, severe damage to vegetation, increased symptoms for people with heart disease, chronic respiratory disease or asthmatics, a decrease in performance by athletes during heavy exercise, and soiling of property and a decrease in visibility. When the AQI is 100 or more, air quality is very poor and health effects are more noticeable. Table 4 is a summary of the AQI pollutants and their impacts.

The AQI for Sarnia is based on ambient air measurements conducted at Centennial Park, station 14064. From the start of the AQI on June 1 until the end of 1988 the AQI was in the good or very good category 98% of the time. Air quality was moderate 1.99% of the time and poor 0.04% of the time. The moderate conditions were caused primarily by elevated levels of ozone although particulates did cause a brief moderate condition. Poor conditions were reached for two hours due to elevated ozone levels with 56 being the maximum AQI reached. The elevated ozone concentrations were largely a result of long-range transport. A summary of the AQI information appears in Table 5.

Table 5. Summary of Air Quality Index from June 1 to
December 31, 1988 at Sarnia.

AQI Description (numerical range)		Number of Hours	Percentage of Time
Very good and good (0-31) Total		5028	98.0
Moderate			
	Ozone	100	1.95
(32-49)	Soiling index	2	.04
	Total	102	1.99
Poor Ozone		2	0.04
(50-99)	Total	2	0.04
Very Poor			
(100+)	Total	0	0

Maximum AQI Poor = 56 (ozone)

TOTAL REDUCED SULPHUR

Gaseous total reduced sulphur compounds often exhibit malodours at very low concentrations. Mercaptans are reduced sulphur compounds that contain sulphur and hydrogen and exhibit characteristics similar to hydrogen sulphide. Hydrogen sulphide, also a reduced sulphur compound, is commonly referred to as "rotten egg gas" and many mercaptans are also malodorous at extremely low concentrations.

Both hydrogen sulphide and mercaptans originate in nature from anaerobic decomposition of organic matter containing sulphur. In the Sarnia area, the release of hydrogen sulphide and mercaptans into the atmosphere may result from the processing of petroleum feedstocks containing sulphur.

The criterion established to represent desirable ambient air quality with respect to hydrogen sulphide is 0.02 ppm as an average for 1 hour. This criterion is based on the offensive odours exhibited by this gas. Similarly, the criterion for mercaptans is based on odour and was established as 0.01 ppm averaged for 1 hour and expressed as methyl mercaptan.

Unfortunately, the continuous monitoring instruments used in North America do not segregate hydrogen sulphide from mercaptans but determine their combined concentrations and express these concentrations as hydrogen sulphide. For the purpose of this report the combined concentrations of hydrogen sulphide and mercaptans are compared to the less restrictive hydrogen sulphide criterion.

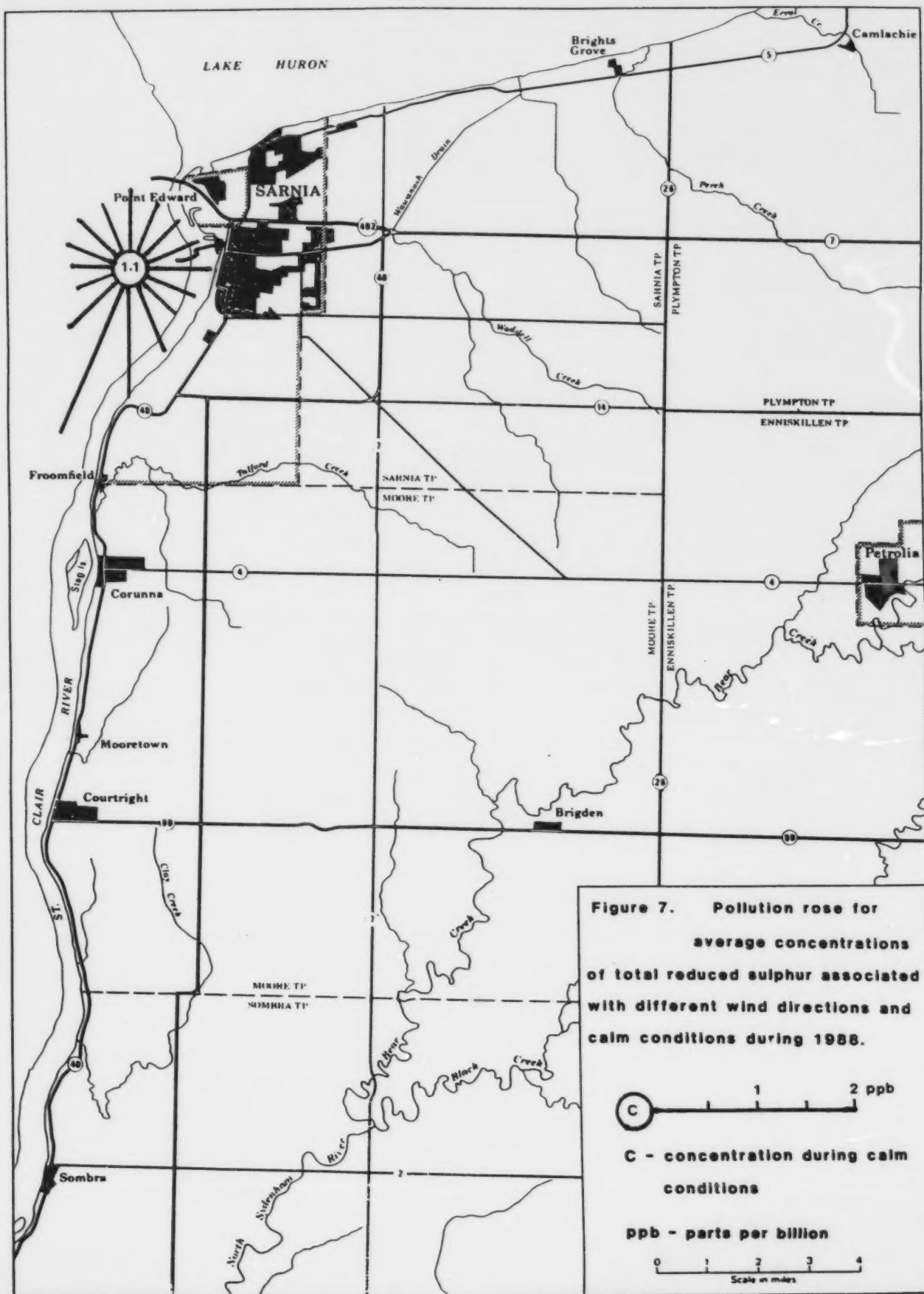
During 1988 monitoring was conducted at station 14064 in the downtown area. There were no excursions detected above the 1-hour criterion. A pollution rose, Figure 7, constructed for total reduced sulphur measurements at station 14064 indicates that higher levels occur when winds are blowing towards the monitoring stations from the industrialized area in south Sarnia. A summary of total reduced sulphur data appears in Table A5, Appendix 4.

CARBON MONOXIDE

Combustion processes represent man's major emissions of carbon monoxide. Emissions from motor vehicles are most significant because they occur near ground level and are concentrated in urban areas where the public may be exposed for lengthy periods. Industries and power generating plants normally provide adequate dispersion for their emissions to prevent unsatisfactory levels of carbon monoxide in the ambient air.

The criteria for carbon monoxide, which are based on the protection of human health, are 30 ppm averaged for 1 hour and 13 ppm averaged for any consecutive 8-hour period.

During 1988 carbon monoxide was monitored at station 14064, located in the downtown core at Centennial Park. The criteria for desirable ambient air quality were not exceeded. A summary of data for carbon monoxide measured at station 14064 since 1978 is presented in Table A5, Appendix 4, and illustrates long-term conformity below established criteria.



OXIDES OF NITROGEN

Gaseous oxides of nitrogen are emitted into the atmosphere by man through combustion processes. Nitric oxide and nitrogen dioxide are the gaseous compounds of primary interest.

Criteria for desirable ambient air quality exist for nitrogen dioxide, but not for nitric oxide or total oxides of nitrogen. The criteria, which are based on offensive odours and the protection of human health, are 0.20 ppm averaged for 1 hour and 0.10 ppm averaged for 24 hours. The 24-hour criterion has not been exceeded at station 14064 where monitoring began in 1978. The 1-hour criterion was not exceeded in 1988 and has only been exceeded once since 1978.

A summary of data for oxides of nitrogen appears in Table A5, Appendix 4. Levels are in ranges typical of communities the size of Sarnia.

Oxides of nitrogen in combination with reactive hydrocarbons and certain meteorological conditions play an important role in the formation of unsatisfactory levels of photochemical oxidants. Also, oxides of nitrogen react to form acids which are part of acidic precipitation. Therefore, consideration is being given to further controls on emissions of oxides of nitrogen. One such control recently implemented is stricter controls for emissions from new cars. As well, legislation is being developed that will require point sources to reduce emissions.

HYDROCARBONS

Emissions from motor vehicles are a primary man-made source of hydrocarbons in ambient air. Other significant man-made sources are incomplete combustion of fuels by

industries and power plants, and evaporation losses during the manufacture, use, storage and transportation of materials containing volatile hydrocarbons. Natural phenomena also produce many hydrocarbons of which methane is the most abundant.

Owing to the wide range of effects associated with different hydrocarbons at various concentrations, no criteria for desirable ambient air quality have been established for total hydrocarbons. Instead control is achieved by setting criteria for desirable levels of specific hydrocarbons in ambient air and/or establishing standards which require control of emissions of specific hydrocarbons.

Total hydrocarbons have been measured at station 14064 in Centennial Park since July, 1978. Average levels of total hydrocarbons have been similar each year. A summary of data for hydrocarbons appears in Table A5, Appendix 4.

The Ministry has conducted a number of short term intensified monitoring surveys in the Sarnia area using mobile vans. These surveys have measured numerous specific hydrocarbons at low levels.

OXIDANTS

Oxidants in the ambient air are primarily a result of a series of photochemical reactions and inter-reactions involving oxides of nitrogen and non-methane hydrocarbons. The reactions are promoted by certain meteorological conditions such as warm temperatures and intensive sunshine, resulting in higher levels of oxidants in the spring and summer months.

Throughout 1988 the Ministry monitored oxidants in the form of ozone at station 14064 in the downtown core of Sarnia and at station 14118, situated in a rural setting approximately 10 kilometres east of Sarnia. Ozone normally accounts for 80 to 95 percent of the oxidants present in ambient air. Consequently, with technology for monitoring ozone being more accurate and efficient than for total oxidants, most regulatory agencies monitor for ozone.

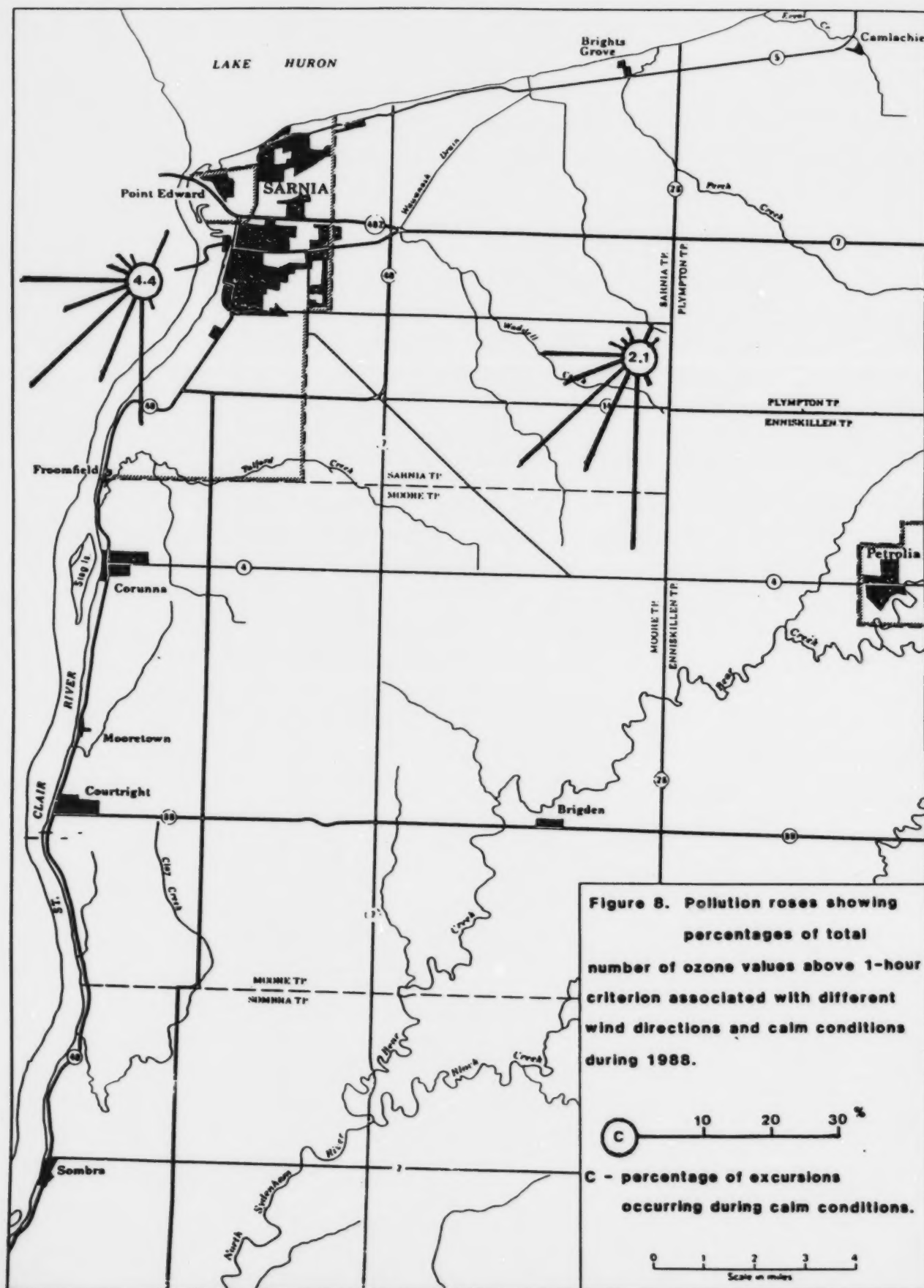
Long-range transport of ozone and its precursor chemicals (oxides of nitrogen and hydrocarbons) may account for a very significant portion of local levels of ozone. Long-range transport from distances greater than 200 kilometres has been reported in the literature. Therefore, successful control of oxidants will depend on control strategies implemented in the United States as well as Ontario. The United States and Canada have been jointly addressing the significance of long-range transport of ozone and its precursor chemicals. The United States Environmental Protection Agency required individual states to implement control strategies that would ensure attainment of the primary air quality standard for ozone (0.12 ppm, averaged for 1 hour) by December, 1987. However, some states have not met the deadline and extensions have been granted. Ontario has launched a detailed study into oxidants and oxidant control strategies. New emission control requirements for new cars in Canada should have a positive effect on ozone levels by reducing hydrocarbon and oxides of nitrogen emissions. Also, even more stringent controls for motor vehicles are planned and some controls scheduled to reduce acid precipitation will reduce ozone precursors. In October 1988, the federal and provincial ministers requested that a comprehensive national plan be developed to further manage nitrogen oxides and volatile organic compound emissions in Canada.

In addition to ozone formed by photochemical reactions in the troposphere, ground level concentrations of ozone are occasionally increased by ozone from the stratosphere being transported downward. Ozone is naturally produced in minor amounts by lightning.

Ontario's criterion for desirable ambient air quality established for ozone is 80 parts per billion (ppb) averaged for 1 hour. This criterion was established for the protection of vegetation, property and human health. Some oxidant-related effects that are detrimental to health are eye irritation and a decrease in performance during athletic endeavors.

During 1988 the 1-hour criterion was exceeded 125 times at station 14064 and 239 times at station 14118. The more frequent excursions in the rural location of station 14118 is not surprising. With long-range transport accounting for the majority of the elevated ozone values rural locations are subjected to frequent high levels of ozone. In urban areas sometimes the elevated ozone levels imported by long-range transport are reduced through ozone being scavenged by other pollutants more prevalent in urban air than in rural air. Results from two ozone monitors operated by the Lambton Industrial Society follow the same pattern of fewer ozone excursions being measured at the site in downtown Sarnia. A summary of data for ozone appears on Table A6 of Appendix 4.

Pollution roses for 1988 are presented in Figure 8 to show the frequency of the total number of excursions above the criterion associated with different wind directions. At both stations the greatest frequency of excursions are associated with winds from the southwest quadrant. These



winds are apt to be associated with the backs of high pressure systems or the area south of low pressure fronts which have weather favourable for photochemical reactions (clear sunny skies and warm temperatures) and which promote long-range transport of oxidants and their precursor chemicals.

FLUORIDES

In the Sarnia area fluorides are emitted into the atmosphere from fossil-fueled power plants where it exists as an impurity in coal, from a fertilizer plant where it occurred as a constituent of phosphorus rock and remains in gypsum ponds, and from petroleum refineries where it is used as a catalyst in alkylation.

Fluoridation rate is a measurement designed to indicate relative amounts of gaseous fluoride present over an extended period of time. A lime-impregnated filter is exposed to ambient air for thirty days and subsequently analyzed for fluoride content. This technique is inexpensive compared to other methods for measuring fluorides. Some fluorides in particulate form are collected on the filters.

Criteria for desirable ambient air quality established for fluoridation rate are based on protection of sensitive vegetation. A criterion of 40 micrograms of fluoride per 100 square centimetres of filter per 30 days ($\text{ug F}/100 \text{ cm}^2/30 \text{ days}$) exists for the growing season of April 15 to October 15. A less stringent criterion of 80 $\text{ug F}/100 \text{ cm}^2/30 \text{ days}$ exists for the period of October 16 to April 14. Since the months of April and October are common to both criteria and fluoridation rate is determined on a monthly basis, excursions above the criteria during these months are determined by comparing fluoridation rate to the average of the two criteria ($60 \text{ ug F}/100 \text{ cm}^2/30 \text{ days}$).

The Ministry monitors fluoridation rate at station 14004, located south of Courtright in the vicinity of the fertilizer complex of Canadian Industries Limited and power generating plants of Ontario Hydro and Detroit Edison. Canadian Industries Limited has maintained a detailed monitoring network for fluoridation rate for many years. Table 6 presents the Ministry data for fluoridation rate from 1976 through 1988.

Canadian Industries Limited shut down its phosphoric acid plant in 1986 resulting in a reduction in fluoride emissions. The annual average fluoride values for 1987 and 1988 are appreciably lower than those of the pre-shutdown period. However, the growing season criterion for fluoridation rate continues to be exceeded at station 14004. Therefore, phytotoxicology surveys of the vegetation in the area should be continued. In recent years these surveys have not revealed damage to vegetation attributable to fluorides off the property of Canadian Industries Limited. The absence of vegetation damage with the excursions above the growing season criterion may be attributable to the absence of very sensitive vegetation.

CONCLUSIONS

The ambient air monitoring program for traditional air pollutants revealed unsatisfactory air quality in the Sarnia area attributable to ozone and suspended particulate matter. The unsatisfactory levels of ozone are primarily attributable to the transboundary flow of ozone and precursor chemicals from the United States into Ontario. The unsatisfactory levels of suspended particulate matter were greatly reduced with the closing of Homes Foundry in September, 1988.

Fluoride levels have been lower in recent years due to reduced emissions from Canadian Industries Limited while sulphur dioxide levels continue to be well controlled by the Lambton Industrial Meteorological Alert regulation.

Table 6. Fluoridation rates measured at station 14004 from 1976 to 1988 (ug F/100 cm³/30 days)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Average
1976						<u>46</u>	<u>38</u>	<u>74</u>	<u>48</u>	<u>39</u>	<u>21</u>	<u>40</u>	<u>44</u>
1977	<u>42</u>	<u>23</u>	<u>53</u>	<u>32</u>	<u>78</u>	<u>32</u>		<u>79</u>	<u>112</u>	<u>29</u>	<u>104</u>	<u>50</u>	<u>58</u>
1978	<u>83</u>	<u>51</u>	<u>53</u>	<u>57</u>	<u>100</u>	<u>65</u>	<u>94</u>	<u>74</u>	<u>74</u>	<u>57</u>	<u>53</u>	<u>59</u>	<u>68</u>
1979	<u>32</u>	<u>63</u>	<u>25</u>	<u>56</u>	<u>54</u>	<u>64</u>	<u>68</u>	<u>129</u>	<u>89</u>	<u>49</u>	<u>32</u>	<u>26</u>	<u>57</u>
1980	<u>16</u>	<u>23</u>	<u>51</u>	<u>62</u>	<u>61</u>	<u>49</u>	<u>83</u>	<u>84</u>		<u>36</u>	<u>28</u>	<u>31</u>	<u>48</u>
1981	<u>48</u>	<u>48</u>	<u>30</u>	<u>49</u>	<u>69</u>	<u>78</u>	<u>116</u>	<u>122</u>	<u>95</u>	<u>71</u>	<u>55</u>	<u>24</u>	<u>67</u>
1982	<u>48</u>	<u>67</u>	<u>35</u>	<u>35</u>	<u>99</u>	<u>20</u>	<u>50</u>		<u>38</u>	<u>86</u>	<u>35</u>	<u>20</u>	<u>48</u>
1983	<u>17</u>	<u>30</u>	<u>37</u>	<u>42</u>	<u>43</u>	<u>75</u>	<u>60</u>	<u>68</u>	<u>42</u>	<u>73</u>	<u>30</u>	<u>30</u>	<u>46</u>
1984	<u>27</u>	<u>36</u>	<u>45</u>	<u>80</u>	<u>56</u>	<u>61</u>	<u>54</u>	<u>71</u>	<u>43</u>	<u>56</u>	<u>25</u>	<u>30</u>	<u>49</u>
1985	<u>37</u>	<u>27</u>	<u>34</u>	<u>40</u>	<u>39</u>	<u>47</u>	<u>45</u>	<u>89</u>	<u>58</u>	<u>31</u>	<u>50</u>	<u>32</u>	<u>44</u>
1986	<u>27</u>	<u>43</u>	<u>30</u>	<u>46</u>	<u>66</u>	<u>82</u>		<u>57</u>	<u>96</u>	<u>41</u>	<u>29</u>	<u>53</u>	<u>52</u>
1987	<u>25</u>	<u>23</u>	<u>31</u>	<u>33</u>	<u>24</u>	<u>55</u>	<u>37</u>	<u>57</u>	<u>34</u>	<u>20</u>	<u>24</u>	<u>19</u>	<u>32</u>
1988	<u>15</u>	<u>19</u>	<u>25</u>	<u>24</u>	<u>42</u>	<u>36</u>	<u>68</u>	<u>45</u>	<u>56</u>	<u>18</u>	<u>28</u>	<u>19</u>	<u>33</u>

Note: Underlined values exceeded criteria for desirable ambient air.

APPENDIX I

MONITORING NETWORK

Table A1. Locations of monitoring stations and parameters being monitored.

Station	Location	Parameters Measured	Height of Measurements	Purpose of Stations and Comments
14001	Sarnia General Hospital	Suspended particulates	16 m.	Historical station which has been in operation since 1962. Does not reflect ground level concentrations but does indicate more direct effects of particulates from high stacks and long-range transport.
14004	5 1/2 miles south of Courtright	Fluoridation rate	4 m.	Monitors fluorides from fertilizer industry.
14016	1 1/2 miles south of Courtright	Suspended particulates continuous SO ₂ , WS, WD, Temp., WS, WD, Temp., WS, WD, Temp., telemetering equipment	1 m. 10 m. 30 m. 92 m.	Monitors suspended particulates and sulphur dioxide in relation to power generating plants. Provides meteorological data required for stability forecasts and air quality interpretations.
14030	R.R. #1 Corunna	Suspended particulates	3 m.	Monitors particulates in the vicinity of Tricell Limited.
14031	R.R. #1 Mooretown	Suspended particulates	3 m.	Monitors particulates in the vicinity of Tricell Limited.
14049	Victoria Street	Continuous SO ₂ , CO, NO, NO ₂ , NOx, O ₃ , total hydrocarbons, suspended particulates	4 m.	Monitored air pollutants in a heavily populated area where traffic, commercial establishments and the heavily industrialized complex south of the monitoring station should be high relative to residential areas. This site was terminated in 1978 and the instruments moved to station 14064.
14054	Sarnia Yacht Club	Suspended particulates	5 m.	Monitors suspended particulates in the north Sarnia-Point Edward area.

Table A1. continued - Locations of monitoring stations and parameters being monitored.

Station	Location	Parameters Measured	Height of Measurements	Purpose of Stations and Comments
14059	Riverbend, Corunna	Suspended particulates	4 m.	Monitors suspended particulates in the residential area of Corunna which is surrounded by industry and generating stations.
140064	Centennial Park Front Street, Sarnia	Continuous SO ₂ , CO, NO, NO _x , NO _x , O ₃ , total hydrocarbons, total reduced sulphur. 1-hr COH, suspended particulates, telemetering equipment	3 m.	Monitors main air pollutants in an area adjacent to downtown Sarnia and in line with many point sources of pollution located to the south of the downtown area. Provides Air Pollution Index for Sarnia.
14118	Mandamin, 5 miles west of Wyomaing	O ₃	5 m.	Monitors ozone levels in a rural location.
14151	Front and David Streets, downtown Sarnia	Suspended particulates	3 m.	Monitors pollutants in commercial area which is also affected by heavily industrialized area to south. Since this is the location of a monitoring station operated by the Lambton Industrial Society, cross checking of monitoring techniques is possible.
14152	Christina and Exmouth Streets, Sarnia	Suspended particulates	5 m.	Monitors particulates near Holmes Foundry Limited.
14153	Mara Street, Point Edward	Suspended particulates	9 m.	Monitors suspended particulates near Holmes Foundry Limited.

Table A2. Desirable ambient air quality criteria established by the Ontario Ministry of the Environment.

Parameter	Desirable ambient air quality criteria	Prime reasons for establishing criteria or monitoring parameter
Carbon monoxide	30 ppm averaged for 1 hour 13 ppm averaged for 8 hours	Protection of human health Protection of human health
Fluoridation rate	40 ug of fluorides/100 cm ² of lined filter paper in 30 days during April 15 to October 15	Protection of vegetation
Hydrocarbons	80 ug of fluorides/100 cm ² of lined filter paper in 30 days during October 16 to April 14 None	Protection of vegetation (less restrictive criterion during the non-growing season) Effects of hydrocarbons vary widely depending on their chemical-physical nature
Hydrogen Sulphide	0.02 ppm averaged for 1 hour	Protection against offensive odours
Mercaptans	0.01 ppm averaged for 1 hour	Protection against offensive odours
Nitric oxide	None	Reacts with oxygen to produce NO ₂
Nitrogen dioxide	0.20 ppm averaged for 1 hour	Protection of human health and protection against odours
Oxides of nitrogen	0.10 ppm averaged for 24 hours None	Protection of human health and protection against odours

Table A2. continued
Desirable ambient air quality criteria established by the Ontario Ministry of the Environment.

Parameter	Desirable Ambient Air quality Criteria	Prime reasons for establishing criteria or monitoring parameter
Ozone	0.08 ppm averaged for 1 hour	Protection of vegetation, adverse health effects
Sulphur dioxide	0.25 ppm averaged for 1 hour	Protection of vegetation
	0.10 ppm averaged for 1 day (24 hours)	Protection of human health
	0.02 ppm averaged for 1 year	Protection of vegetation
Suspended particulates	120 ug/m ³ averaged for 24 hours	Based on health effects in conjunction with elevated levels of SO ₂ and impairment of visibility
	A geometric mean of 60 ug/m ³ during 1 year	Based on public awareness of visible pollution
Cadmium in suspended particulates	2.0 ug/m ³ averaged for 24 hours	Protection of human health
Lead in suspended particulates	5 ug/m ³ averaged for 24 hours	Protection of human health
Nickel in suspended particulates	A geometric mean of 2 ug/m ³ over a 30-day period	Protection of human health
	2.0 ug/m ³ averaged for 24 hours	Protection of vegetation
Vanadium in suspended particulates	2.0 ug/m ³ averaged for 24 hours	Protection of human health

APPENDIX 2

METEOROLOGICAL DATA

Table A3. Percent frequencies of wind directions at the
30-metre level of station 14016.

Year	N	NE	E	SE	S	SW	W	NW
1988	15.7	7.1	3.6	7.7	20.3	16.4	15.0	14.2
1987	12.8	10.8	6.8	7.9	19.1	18.1	10.9	13.7
1986	12.6	8.4	7.6	8.4	18.0	18.9	12.2	14.1
1985	12.2	10.0	5.7	7.2	20.5	19.0	12.7	12.8
1984	12.6	9.8	6.1	8.2	22.1	15.6	11.0	14.7
1983	13.5	10.6	7.5	9.3	18.9	15.6	10.2	14.4
1982	12.1	9.5	5.2	8.9	22.4	16.4	12.6	12.9
1981	13.8	9.9	4.5	7.8	18.6	15.8	11.9	17.7
1980	12.6	8.6	5.6	7.5	20.1	15.1	14.4	16.1
1979	10.7	8.7	6.5	8.9	24.7	14.7	11.9	14.0
1978	13.6	12.7	6.3	6.0	19.0	17.2	11.9	13.3
1977	11.3	9.8	5.3	7.2	18.5	21.2	14.1	12.6
1976	12.2	9.2	3.5	4.7	18.1	20.5	15.1	16.7

APPENDIX 3

PARTICULATES

Table A4. Concentrations (ug/m³) of various constituents of suspended particulates: 1976 to 1988.

Station and Year	Cadmium			Chromium			Copper			Iron			Lead		
	# of Samples	Avg.	Max.	# of Samples	Avg.	Max.	# of Samples	Avg.	Max.	# of Samples	Avg.	Max.	Samples	Avg.	Max.
14031															
1978	12	0.002	0.003	12	0.004	0.008	12	0.44	1.00	12	0.7	1.3	12	0.1	0.3
1979	54	0.001	0.005	54	0.010	0.189	54	0.25	0.97	58	0.5	2.7	54	0.1	0.4
1980	54	0.001	0.004	54	0.005	0.030	54	0.13	0.26	54	0.5	2.2	54	0.1	0.3
1981	58	0.001	0.003	58	0.005	0.035	58	0.15	0.95	58	0.6	2.6	58	0.1	0.2
1982	54	0.000	0.002	56	0.004	0.010	58	0.13	0.29	50	0.5	3.7	56	0.1	0.6
1983	55	0.001	0.001	53	0.002	0.012	55	0.25	1.54	55	0.6	2.3	55	0.1	0.3
1984	50	0.001	0.002	50	0.004	0.032	50	0.14	0.37	50	0.5	1.9	50	0.1	0.1
1985	55	0.001	0.004	55	0.007	0.029	55	0.06	0.13	55	0.6	2.3	55	0.1	0.1
1986	50	0.000	0.003	50	0.006	0.024	50	0.07	0.16	50	0.3	1.1	50	0.0	0.1
1987	56	0.000	0.002	56	0.006	0.015	56	0.05	0.12	56	0.4	2.3	56	0.0	0.1
1988	55	0.000	0.003	55	0.006	0.020	55	0.02	0.06	55	0.5	4.3	55	0.0	0.0
14064															
1981	57	0.001	0.004	57	0.003	0.013	57	0.17	0.86	57	0.7	2.3	59	0.1	0.6
1982	52	0.001	0.008	47	0.002	0.009	52	0.21	1.66	53	0.7	2.9	50	0.2	1.1
1983	57	0.001	0.003	57	0.002	0.009	57	0.62	2.50	57	0.7	1.8	56	0.2	0.6
1984	57	0.001	0.002	57	0.002	0.015	57	0.43	2.00	57	0.5	1.7	57	0.2	0.3
1985	57	0.001	0.003	57	0.006	0.012	57	0.11	0.39	57	0.6	2.3	57	0.1	0.3
1986	57	0.000	0.002	57	0.005	0.023	57	0.20	0.64	57	0.5	1.5	57	0.1	0.3
1987	59	0.001	0.004	59	0.005	0.010	59	0.23	1.02	59	0.5	2.6	59	0.1	0.2
1988	58	0.001	0.005	58	0.008	0.050	58	0.31	1.51	58	0.7	3.9	58	0.0	0.1
14152															
1987										87	1.8	12.6	87	0.1	0.5
1988										115	2.6	26.7	115	0.1	0.7
14153															
1987										81	1.1	5.5	81	0.1	0.7
1988										115	1.1	7.3	115	0.0	0.6

APPENDIX 4

TOTAL REDUCED SULPHUR

CARBON MONOXIDE, OXIDES OF NITROGEN,

HYDROCARBONS AND OZONE

Table A5. Summary of data for total reduced sulphurs, carbon monoxide, oxides of nitrogen and hydrocarbons.

Pollutant and Criteria	Station Number	YEAR										
		1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Total reduced sulphur												
Annual average (ppm)	14064	0.001	0.001	0.000	0.000	0.001 (b)						
Percentage of values above 1-hour criterion (a)	14064	0.00	0.00	0.00	0.02	0.19 (b)						
Carbon Monoxide												
Annual average (ppm)	14064	0	0	0	0	0	0	0	0	0	0	0
Percentage of values above 1-hour criterion	14064	0	0	0	0	0	0	0	0	0	0	0
Percentage of values above 8-hour criterion	14064	0	0	0	0	0	0	0	0	0	0	0
Note:		(a)	Criterion for hydrogen sulphide (0.02 ppm)									
		(b)	4 months of data									

Table A5. continued
Summary of data for total reduced sulphurs, carbon monoxide, oxides of nitrogen and hydrocarbons.

Pollutant and Criteria	Station Number	YEAR										
		1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Nitric oxide												
Annual average (ppm)	14064	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
Nitrogen dioxide												
Annual average (ppm)	14064	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Percentage of values above 1-hour criterion	14064	0	0	0	0	0	0	0.01	0	0	0	0
Percentage of values above 24-hour criterion	14064	0	0	0	0	0	0	0	0	0	0	0
Total oxides of nitrogen												
Annual average (ppm)	14064	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03
Total hydrocarbons												
Annual average (ppm)	14064	2.0	2.0	1.6	2.0	2.0	2.0	2.1	2.1	1.9	2.0	1.7

Table A6. Summary of data for ozone

Station and Parameter	YEAR											
	1968	1967	1966	1965	1964	1963	1962	1961	1960	1979	1978	1977
Station 14064												
Annual average (ppm)	0.023	0.022	0.021	0.023	0.023	0.023	0.023	0.021	0.022	0.023	0.018(a)	
Number of values above 1-hour criterion	125	44	30	47	80	116	56	67	68	130	56(a)	
Percentage of values above 1-hour criterion	1.5	0.5	0.4	0.6	1.0	1.4	0.7	0.8	0.8	1.6	1.4(a)	
Station 14118												
Annual average (ppm)	0.030	0.026	0.024	0.026	0.026	0.019	0.023	0.023	0.022	0.027	0.029	0.027
Number of values above 1-hour criterion	239	133	41	25	120	16	10	85	39	138	249	182
Percentage of values above 1-hour criterion	2.8	1.6	0.5	0.6(a)	1.6	0.2	0.1	1.0	0.5	1.7	3.5	2.6

Note: (a) based on 6 months.